REMARKS

In response to the Official Action dated April 1, 2003, applicant respectfully traverses the rejections and requests reconsideration.

The claims and the body of the specification have been amended to better define the invention. The amended specification is enclosed as Attachment A. The new slate of claims is enclosed as Attachment B.

THE §102 REJECTIONS:

Claims 1-17 have been rejected as anticipated by Nomura et al. Claims 1-10, 12 and 14 have been rejected as anticipated by Cheon et al.

Claim 18 claims a method of depositing an epitaxial II-VI semiconductor film on a single crystalline substrate. The method comprises the step of providing the single crystalline substrate suitable for epitaxial film growth and with a structure and lattice constant which approximate that of the II-VI semiconductor film. The method further comprises the steps of generating a flow of II-VI semiconductor single source precursor and directing the flow towards the single crystalline substrate. In addition, the method comprises the step of heating the single crystalline substrate to effect the composition of the single source precursor in the proximity of the substrate to deposit the II-VI semiconductor film on the substrate. The single source precursor flow and the substrate temperature are selected so that the II-VI semiconductor film that is deposited is epitaxial. Claims 19-28 are dependent on claim 18. Further, the film themselves grown by the claimed method are claimed in claims 29 and 30.

The present invention is focused on the growth of epitaxial films. The application defines on page 1, lines 12-14, that the term "epitaxial" is used for a film that is grown with singular crystallographic orientation in all directions. In particular, this requires that there is a relation between the crystallographic structure of the substrate and the film which is grown on the substrate. In effect, an epitaxial film continues to grow with the same or similar crystallographic structure that the substrate has; from a structural point of view the film may therefore be seen as an extension of the substrate.

In order to distinguish the present invention from prior art, it is necessary to distinguish epitaxial films from self-textured films. Self-textured films have a uniform orientation in a direction perpendicular to the substrate but have random in-plane orientation (in-plane and out-of-plane referring to the plane of the substrate). Here the driving force is the surface free energy of material that is deposited on the substrate. For example, cubic zinc sulfite grows on any substrate that is sufficiently flat self-textured with a preferred (111)-orientation. The reason for this preferred orientation is that the film is in a state of lowest energy if the (111)-plane is exposed and therefore the film orientation is driven towards this orientation. Such "self-textured" films may be grown using a variety of film growing techniques including CVD. Often a buffer layer forms at the interface between the substrate and the film which effectively isolates the substrate from the self-textured film and on which the self-textured film is floating. In contrast to epitaxy, self-texturing is a phenomena that is substrate independent.

The publication by Nomura et al. discloses the growth of zinc sulfide films using single source CVD. It is pointed out that (111)-oriented cubic zinc sulfide films were grown on silicon (111), using a carrier gas to support the flow of the precursor flux. The

film structure is characterized using X-ray diffraction (XRD) patterns obtained in the 2-theta method. Prior to film growth, the substrate is washed using a process that is not further described. Reference is being made to reference 13, an earlier publication by Nomura, but this reference also does not further describe how the substrate was cleaned. Films were then grown using evaporated precursor with a flow that was supported by an argon carrier gas.

In principle, the analysis techniques that were used by Nomura et al. to characterize the films cannot give evidence if the films are epitaxial or not. The 2-theta method generally only analyses the out-of-plane orientation of a film. That is, the orientation of the film in a direction perpendicular to the substrate. Geometry permits that no evidence can be obtained from such a XRD measurement on the in-plane orientation of the film, namely, if the film is of a singular orientation in directions within the plane of the substrate which, of course, is a critical issue to determine if the film is epitaxial. Therefore, the data presented in the Nomura citation does not give any indication if the films are epitxial. Further, the fact that cubic ZnS films on cubic Si(III) were only obtained using a carrier gas which supports the precursor flux would suggest that the formed films are clearly not epitaxial. It is known that in particular epitaxial films require the slow growth of the films as decomposed precursor molecules need to have sufficient "time to adjust" to the right lattice positions that are dictated by the substrate before further molecules arrive. In general, the quality of epitaxial films improves the slower the films are grown. Without the carrier gas, however, the films grown by Nomura were of a <u>hexagonal</u> structure (see last column lines 29-32) and, therefore, far from epitaxial.

The growth techniques that were used strongly suggest that the films are merely self-textured films. In fact, Nomura et al. does not claim that epitaxial films were grown; it is only claimed that the films have a (111) orientation (see last paragraph) – it is therefore only claimed that the films are self-textured. In summary, there is no disclosure of epitaxial films in the Nomura citation and the growth conditions that were used teach away from epitaxial film growth.

In contrast, the inventors of the present invention have developed a method that can be utilized for the growth of epitaxial, that is single crystalline, films on silicon (III) substrates. A single source precursor is utilized and growth conditions, such as flow of precursor, and substrate temperature are carefully selected so that epitaxial growth conditions can be achieved.

The Official Action takes the position that claims 1-10 and 12-14 are anticipated by Cheon et al. who disclose that the growth is the CVD growth of CdS and films and ZnS films on quartz. Quartz is the single crystalline form of SiO_2 and has a lattice constant and a structure that is hugely different to that of zinc sulfide and cadmium sulfide. Therefore, it is clearly impossible to grow epitaxial film on quartz. Cheon et al. describe that it is possible to grow the films so that one crystallographic axis is oriented perpendicular to the substrate. In other words, the films are self-textured (see lines 5-7 of column 2). In contrast, the present invention is concerned with the growth of epitaxial films.

In view of this Amendment and the new claims, it is submitted that this application is now in condition for allowance. Should the Examiner believe that a

personal interview would advance the conclusion of the prosecution of this application, the Examiner is invited to call the undersigned at (703) 739-4900.

ATTACHMENT A
Amendments to the Specification

Please replace the paragraph at page 2, lines 2-5 with the following amended paragraph.

~~In accordance with a first aspect of the~~ The present invention ~~there is provided~~ provides method of depositing an epitaxial ~~zinc-based~~ II-VI semiconductor film ~~grown using~~ on a single-crytalline substrate comprising the steps of ~~source chemical vapour deposition.~~

- providing the single-crystalline substrate suitable for epitaxial film growth with a structure and lattice constant which approximate that of the II-VI semiconductor film,
- generating a flow of II-VI semiconductor precursor and directing the flow towards the single-cyrstalline substrate and
- heating the single-crystalline substrate to effect decomposition of the single source precursor in the proximity of the substrate so that the II-VI semiconductor film is deposited on the substrate

wherein the single source precursor flow and the substrate temperature are selected so that the II-VI semiconductor film that is deposited on the single crystalline substrate is epitaxial.

Please replace the paragraph at page 2, line 6 with the following amended paragraph.

~~In one embodiment, the~~ The epitaxial film may comprise any II-VI semiconductor material, but preferably comprises ZnS.

Please delete the paragraph at page 2, lines 7-9.

Please replace the paragraph at page 2, lines 10-12 with the following amended paragraph.

~~In another preferred embodiment, the~~ The ZnS ~~is~~ may be grown using $Zn(S_2CNR_2)_2$, where R comprises an alkyl group, as a precursor for the single source chemical vapour deposition. The number of carbon atoms in the alkyl group is preferably in the range from 1 to 6.

Please delete the paragraph at page 2, lines 13-14.

Please delete the paragraph at page 2, lines 15-19.

Please delete the paragraph at page 2, line 20.

Please replace the paragraph at page 2, lines 21-23 with the following amended paragraph.

~~In another preferred embodiment, the~~ The ZnS is grown using ~~$Zn(S_2CNR_2)_2$, where R comprises an alkyl group,~~ zinc diethyldithiocarbamate as ~~a~~ precursor ~~for the single source chemical vapour deposition~~.

Please delete the paragraph at page 2, lines 24-26.

Please delete the paragraph at page 2, lines 27-28.

Please replace the paragraph at page 2, lines 29-30 with the following amended paragraph.

~~Preferably, the~~ The single crystalline substrate preferably comprises a silicon (111) ~~substrate~~. The temperature of the heated substrate preferably is selected to be within the range of 350-450°C and most preferably is approximately 400°C.

Please delete the paragraph at page 2, lines 31-34.

Please delete the paragraph at page 2, line 35.

Please delete the paragraph at page 2, line 36.

Please replace the paragraph at page 3, lines 1-10 with the following amended paragraph.

~~In accordance with a fourth aspect of the present invention, there is provided a process for growing an epitaxial zinc-based II-VI semiconductor film, the process comprising the steps~~ The method preferably comprises the initial step of cleaning a single crystalline substrate~~, heating the substrate to a deposition temperature, the sublimation of a single source chemical vapour deposition precursor;~~

~~the pyrolysis of the precursor molecules on the heated substrate; and~~

~~the formation of the epitaxial film on the heated substrate~~ which includes repeated cycles of rinsing in H_2O.

Please delete the paragraph at page 3, line 11.

Please delete the paragraph at page 3, line 12.

Please replace the paragraph at page 4, lines 6-16 with the following amended paragraph.

Referring initially to Figure 1, a method of depositing a II-VI semiconductor film and an epitaxial film deposited by the method according to a preferred embodiment of the present invention are now described. ~~In~~ Figure 1~~,~~ shows a high vacuum deposition chamber 10 (base pressure 10^{-7} Torr) which comprises a resistively heated Knudsen cell 12 loaded with a zinc diethyldithiocarbamate precursor powder (not shown) for the

single source chemical vapour deposition (SSCVD). A silicon Si(111) substrate 19 is mounted on a sample holder 16 on a heater 100 and the epitaxial film (not shown) is formed on the substrate 19. The chamber 10 further comprises a view port 11, a port 13 to which a vacuum pump (not shown) is connected and a flexible flange 15 as part of a x,y,z manipulator 17 for the heater 100.

Please delete the paragraph at page 9, lines 13-18.

Please delete the paragraph at page 9, lines 19-24.

ATTACHMENT B
Amendments to the Claims

This listing of claims will replace all prior versions, and listings, of claims in the application.

Claims 1-17. (Canceled).

18. (New) A method of depositing an epitaxial II-VI semiconductor film on a single-crystalline substrate comprising the steps of:

- providing the single-crystalline substrate suitable for epitaxial film growth with a structure and lattice constant which approximate that of the II-VI semiconductor film,
- generating a flow of II-VI semiconductor precursor and directing the flow towards the single-crystalline substrate and
- heating the single-crystalline substrate to effect decomposition of the single source precursor in the proximity of the substrate so that the II-VI semiconductor film is deposited on the substrate,

wherein the single source precursor flow and the substrate temperature are selected so that the II-VI semiconductor film that is deposited on the single crystalline substrate is epitaxial.

19. (New) The method as claimed in claim 18 wherein the II-VI semiconductor is ZnS.

20. (New) The method as claimed in claim 19 wherein the single source precursor is zinc diethyldithiocarbamate.

21. (New) The method as claimed in claim 18 wherein the single source precursor is $Zn(S_2CRN_2)_2$, where R comprises an alkyl group.

22. (New) The method as claimed in claim 21, wherein the number of carbon atoms in the alkyl group is in the range from 1 to 6.

23. (New) The method as claimed in claim 18 wherein the single-crystalline substrate comprises silicon (111).

24. (New) The method as claimed in claim 18 wherein the temperature of the heated substrate is selected to be within the range of 350-450°C.

25. (New) The method as claimed in claim 24 wherein the temperature is approximately 400°C.

26. (New) The method as claimed in claim 18 wherein the single-crystalline substrate is silicon (111), the II-VI semiconductor film is formed from ZnS and the single source precursor is zinc diethyldithiocarbamate.

27. (New) The method as claimed in claim 18 comprising the initial step of cleaning the single crystalline substrate which includes repeated cycles of rinsing in H_2O.

28. (New) The method as claimed in claim 18 wherein the single-crystalline substrate is silicon (111), the II-VI semiconductor film is formed from ZnS, the single source precursor is zinc diethyldithiocarbamate and the method comprises the initial step of cleaning the single crystalline substrate which includes repeated cycles of rinsing in H_2O and wherein the temperature of the heated substrate is selected to be within the range of 350-450°C.

29. (New) An epitaxial film deposited by the method claimed in claim 18.

30. (New) An epitaxial film deposited by the method claimed in claim 27.